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THE ROUGH-HEADED CORN STALK-BEETLE[1]

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INTRODUCTION

The ravages of (*Ligyrus*) *Euetheola rugiceps* (Lec.) were first brought to the attention of the writers in 1914 (*9, p. 3*).[3] Dr. J. M. Gouldin, of Tappahannock, Essex County, Va., in a letter dated June 26, 1914, stated that some farmers lost nearly their entire corn crop. The late Prof. F. M. Webster, then in charge of Cereal and Forage Insect Investigations, instructed the senior writer to make a personal survey of the situation. This was done early in July, 1914, and showed that serious damage (Pl I, *A*) had occurred on several hundred acres of corn in the vicinity of Tappahannock, Va. At that time the beetles had practically ceased their activities, but specimens were sent to Charlottesville, Va., for life-history studies. Since little was known of the habits of this pest or the means of control, the problem of determining these points was assigned to the Charlottesville laboratory, with the senior writer in charge.

The breeding records obtained from material secured in 1914 were disappointing, and since the locality of the outbreak was rather

[1] *Euetheola rugiceps* (Lec.); order Coleoptera, family Scarabaeidae.
[2] Resigned August 31, 1918.
[3] Reference is made by number (*italic*) to "Literature cited," p. 33.

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inaccessible, temporary headquarters were established in the heart of the infested district, in order to study the problem at first hand. In the spring of 1915 the junior writer was assigned to Tappahannock, where he remained until October. In the meantime detailed studies were being conducted in breeding cages at Charlottesville as a check on the work at Tappahannock. The junior writer returned to Tappahannock in 1916 to complete the data on the life history and to start field experiments for controlling the pest, the results of which have already been published in brief (*9*). In this publication it was termed the "rough-headed corn stalk-beetle," a translation of the specific name which seems more appropriate than its earlier name of "sugar-cane beetle," since the insect has been receiving constantly growing emphasis as a corn pest.

ECONOMIC HISTORY

Euetheola rugiceps (Pl. II, *A*) was first named and described by John Le Conte (*8*) in 1856 from specimens obtained in Georgia, and was for a number of years thereafter considered a rather rare southern insect. Riley (*10*) and Comstock (*2*) published the first records of the depredations of this pest in 1880, when it first attracted their attention as a sugar-cane insect on the plantations in Louisiana. Comstock stated that the planters in the infested district claimed to have known the pest and had recognized it as a serious menace to sugar cane for a period of about 20 years preceding the outbreak in the seventies. According to the planters, the first serious outbreak occurred about 1855 or 1856; the next destructive one was in 1875. During 1875 and the two succeeding years the depredations on the sugar-cane plantations caused serious alarm, but there seems to have been a decrease in the activities of the insect in 1879. In 1880 the beetles reappeared and inflicted serious loss. This outbreak was reported by Comstock (*3*). Although both Riley and Comstock incidentally recorded the insect as injuring corn, it was considered primarily a sugar-cane pest and received the vernacular name of "sugar-cane beetle," and by this term it has been designated in the literature until recently. L. O. Howard (*7*) in 1888 was the first to recognize *E. rugiceps* as a corn pest, publishing in that year an account of its depredations to corn in North Carolina and Mississippi. About the same time F. M. Webster (*14*) made similar observations in Arkansas and Louisiana. In 1895 Weed (*15*, *16*) reported losses to corn growers in Mississippi, but, through what was evidently an error in identification, attributed the damage to *Ligyrus gibbosus* which it is now believed never injures corn. Since then depredations by this pest have been reported at rather frequent intervals by an increasing number of investigators, among whom may be mentioned Titus (*13*), Garman (*6*), and Sherman (*11*), the last-mentioned author especially having published an interesting account of the beetle and its work in North Carolina.

The earliest record of injury to corn in Virginia was in 1913, when several farmers reported injury in the "tidewater" section of the State. In the following year the depredations were most severe.

DISTRIBUTION

The known distribution of *Euetheola rugiceps* in the United States is shown in Figure 1. The data upon which the map is based were obtained from the literature, from hitherto unpublished field records and correspondence of the bureau, and from personal correspondence with a number of museum and experiment station entomologists.[4]

Euetheola rugiceps is recorded from all the Southern States lying south of the latitude of Washington, D. C., with the exception of Florida and Oklahoma. Judging by the erratic manner in which the species has been observed to occur in the infested sections of Virginia, it would be inadvisable to draw final conclusions regarding the limits of distribution from the evidence at present available. In Virginia the species was found only in that part of the coastal plain which lies between the Potomac and James Rivers, apparently preferring low, moist, poorly drained soils. Even within the area thus restricted, the species appears at present to be of very unequal distribution, being abundant in certain localities and rare or absent in others. It may be found swarming in certain fields, utterly destroying the corn crop, while other fields of the same general type less than a mile away appear to be uninfested. Doubtless there are unknown factors which influence and limit the spread of this species.

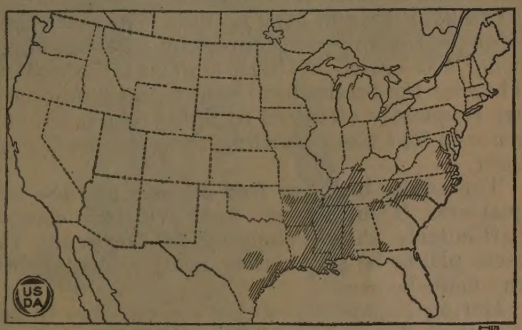


FIG. 1.—Map showing distribution of *Euetheola rugiceps* in the United States

The following is a list of localities, arranged according to States, from which there are records of the occurrence of the species.

Alabama.—Birmingham, Catherine, Carollton, Cleveland, Eutaw, Hampden, Hartsells, Mobile, Sprott.

Arkansas (by counties).—Ashley, Bradley, Clark, Crawford, Cross, Hot Springs, Howard, Jackson, Jefferson, Lincoln, Lonoke, Monroe, Nevada, Perry, Pope, Pulaski, St. Francis.

Georgia.—Bainbridge, Canton, Dalton, Macon.

Kentucky.—Guthrie and Hartford.

Louisiana.—Atchafalaya River, Baldwin, Baton Rouge, Berwick, Breaux Bridge, Broussard, Castille, Clinton, Church Point, Crowley, Donaldsonville, Franklin, Hester, Koran, La Fayette, Mer Rouge, Mill Haven, Monroe, Mound, Morgan City, New Iberia, New Orleans, Oak Grove, Plaquemine, Rayne, Scott, St. James, St. Joseph, Tensas Parish, Ville Platte.

[4] Those who furnished valuable data in this connection include Franklin Sherman, North Carolina Department of Agriculture; J. R. Watson, Florida Agricultural Experiment Station; A. F. Conradi, Clemson College, S. C.; W. V. Reed, Georgia State Board of Agriculture; W. E. Hinds, Alabama Agricultural Experiment Station; J. J. Davis and George G. Ainslie, of the Bureau of Entomology; S. J. Hunter, of the University of Kansas; W. J. Holland, Carnegie Museum; Charles Schaffer, Brooklyn Institute of Arts and Sciences; G. G. Becker, Arkansas Agricultural Experiment Station; H. Garman, Kentucky Agricultural Experiment Station.

Mississippi.—Agricultural College, Brookhaven, Canton, Durant, Greenwood, Gulfport, Kosciusko, Natchez, Ocean Springs, Winona.

North Carolina.—Bostic, Gastonia, Greenville, Monroe, Mount Pleasant, Pantego.

South Carolina.—Cheraw, Union.

Tennessee.—Clarksville, Greeneville, Milan, Savannah, Sevierville.

Texas.—Austin, Beaumont, Fedor, Galveston, Jackson County, New Braunfels, Port Arthur, Victoria.

Virginia.—Achilles, Coles Point, Kinsale, Naxera, Odd, Sharps, Tappahannock.

LIFE HISTORY

GENERAL ACCOUNT

Euetheola rugiceps hibernates in the soil as an adult in or near its normal feeding grounds. It reappears with warm weather, which in Virginia is in late April or early May. At Tappahannock, Va., the earliest dates on which the beetles were found abroad were April 23, 1915, and May 1, 1916. The exact time of their appearance is unquestionably determined by the prevailing weather conditions, being accelerated by high temperatures and retarded by low ones. Thus far the beetles have been found flying only at night, when they are frequently attracted to lights, but it is not an uncommon occurrence to find them crawling upon the surface of the ground in daylight.

The adults begin to feed as soon as they leave their hibernating quarters. Their normal food evidently consists of certain grasses, particularly those belonging to the genus Paspalum, but should these plants be scarce they readily turn their attention to corn, if any fields be near.

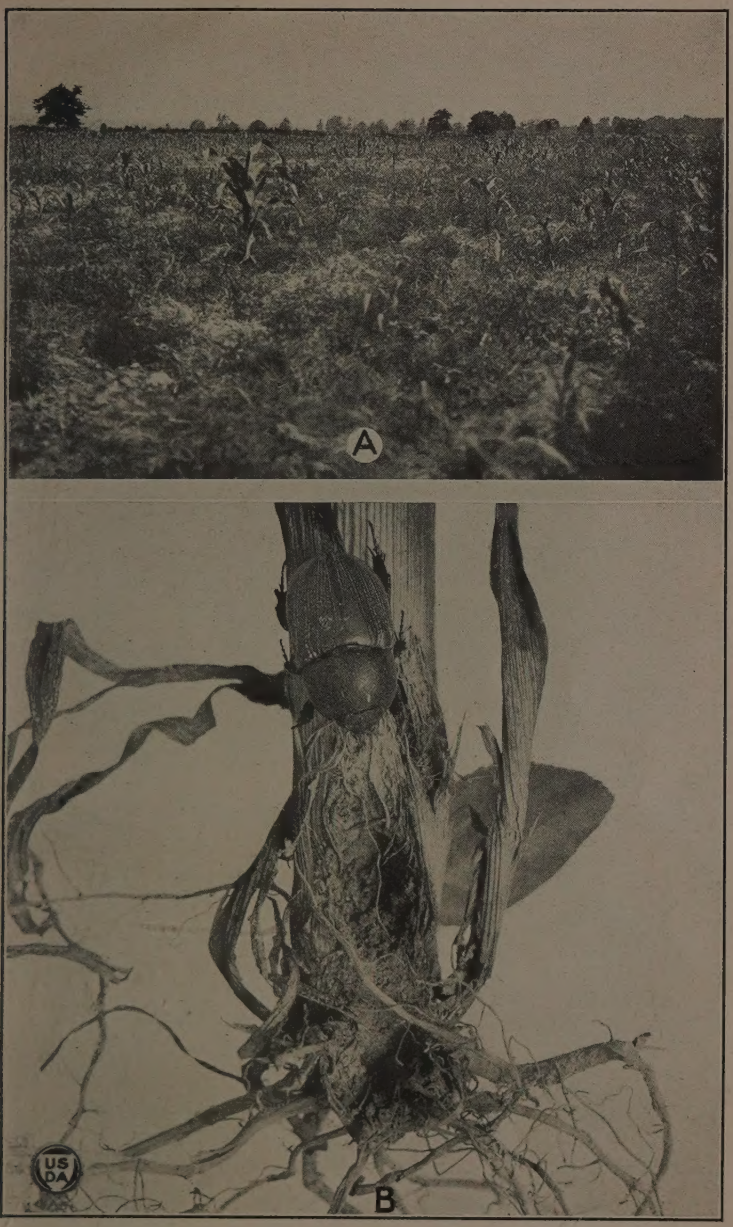
Mating apparently occurs considerably in advance of egg-laying, though it also undoubtedly continues throughout the season of greatest activity, since pairs have been observed *in coitu* after the egg-laying season was well advanced.

Oviposition was observed at Tappahannock chiefly during June, the earliest eggs being found on June 5. The beetles deposit their eggs a few inches below the surface of the ground wherever they happen to be feeding. It therefore appears that this insect spends practically its entire existence below ground. The beetles feed, mate, and oviposit, and the larvæ complete their development below ground.

Under ordinary summer conditions the eggs require from two to three weeks to hatch. When first hatched the larvæ measure about 3 millimeters and when full grown about 32 millimeters or 1¼ inches. The larvæ require from six to eight weeks to reach maturity at Tappahannock, Va. Full-grown larvæ were found from August 2 to October 2, but were most abundant the last week in August and the first week in September. The pupa stage lasts about two weeks under normal weather conditions. The first pupa found in the field at Tappahannock was August 16 in 1915 and August 12 in 1916. The latest field record was November 2, 1916.

The majority of the old beetles die or disappear in midsummer; some stragglers, however, nearly always overlap the new generation. Such stragglers may be easily distinguished by their dull, opaque black, the new ones being highly polished.

Adults of the new generation were found at Tappahannock as early as August 24, but the majority appear during the last half of



THE ROUGH-HEADED CORN STALK-BEETLE

A, Cornfield at Tappahannock, Va., badly damaged by the rough-headed corn stalk-beetle (*Euetheola rugiceps*) (photograph by W. J. Phillips); *B*, corn plant showing typical injury from adult of *E. rugiceps* (photograph by J. H. Paine)

THE ROUGH-HEADED CORN STALK-BEETLE

A, Adult; *B*, egg when first deposited, inclosed within a ball of earth, the latter broken open to show egg within; *C*, egg after development has begun; *D*, end view of egg just before hatching (the dark area is the mandible of the larva showing through the eggshell); *E*, lateral view of egg just before hatching; *F*, larva shortly after hatching. (*A*, photographed by J. H. Paine; *B–F*, by W. J. Phillips)

September. The new generation of beetles do not appear to be very active, remaining usually where they emerge, though they have been found soon after emergence feeding upon the culms of *Juncus effusus* and certain grasses of the genus Paspalum.

EGG

DESCRIPTION

The egg when first laid is oblong, pure white, and perfectly smooth (Pl. II, *B*). Subsequently the egg enlarges until it is nearly double its original size and changes its form until almost globular (Pl. II, *B*, *C*, *D*, and *E*). Eggs measured by the senior writer averaged about 2 millimeters in length and 1.5 millimeters in diameter. These were several days old and approximately full size. No measurements of freshly deposited eggs were made.

METHODS OF COLLECTING AND INCUBATING

A small number of the eggs used in the investigations were gathered in the field, but the greater number were obtained from the breeding cages.

In the field the eggs were found in the ground, where it was usually possible to obtain them by digging.

To obtain eggs which were known with certainty to belong to the present species, adult beetles were confined in suitable breeding cages, from which the eggs were gathered at regular intervals. Each cage consisted of a 12-inch standard-size flowerpot filled with finely-sifted soil and covered with a cylindrical wire-screen top; the whole outfit had essentially the same form and arrangement as that portrayed by Davis (*5*, *pl. 3*, *fig. 4*). The soil in these cages was kept moderately moist, and at intervals, varying from a few days to a week and a half, was passed through a fine-mesh sieve. The meshes in this were fine enough to retain the eggs, which were then transferred to the incubating boxes.

In the breeding cages the beetles were first fed by transplanting young corn plants to the cages, but as the labor of replacing the food plants every few days proved burdensome, a handful or so of corn kernels was buried in the soil. These proved to be a highly satisfactory substitute, the beetles feeding upon them as readily as upon the living plant.

The receptacles used in incubating the eggs were rectangular tin boxes like those used by Davis for the same purpose (*5*, *pl. 4*, *fig. 7*). These boxes were about three-fourths filled with finely-sifted earth, which was kept to the right degree of moisture by occasionally adding a few drops of water with a pipette. As the eggs were transferred to a box each was placed in a small pit made with the blunt end of a pencil, and as the boxes were filled the lid was replaced and they were then kept in the shade. Usually the lid would so conserve the moisture originally in the soil that in most instances it was unnecessary to add more water during the period of incubation.

PLACE OF DEPOSITION

The eggs are deposited in the ground, and apparently the females exercise no particular care in the choice of a place in which to

leave their eggs. As the beetles themselves require a certain degree of moisture in their surroundings, they avoid very dry situations at all times. Naturally the eggs are most frequently encountered in places to which the beetles resort for the purpose of feeding. For this reason they are most numerous in infested cornfields, and in old pastures and grassy waste lands which constitute the normal habitat of the species. Field observations indicate that cornfields, especially if they happen to be well drained and are kept in a good state of cultivation, are generally very unfavorable situations for the subsequent development of the larvæ; for, although eggs are laid abundantly in corn hills, well-grown larvæ were rarely found in the same fields later in the season. This may be plausibly accounted for by the fact that the soil in well cultivated cornfields during periods of high temperature and drought is unsuitable for the development of the larvæ.

MANNER OF DEPOSITION

The process of oviposition has not been observed. In most instances it appears that the eggs are deposited singly, although occasionally several may be found within a space an inch square. They are rarely inclosed in a clearly defined ball of earth. Possibly this may be due to the rather incoherent nature of the soils in which eggs were obtained in Virginia. At Charlottesville some experiments were conducted to ascertain whether the beetles were capable of forming such balls of earth by varying the moisture content of the soil and by adding clay to it. As a result a number of more or less firm balls were obtained, each inclosing a cavity containing a single egg (Pl. II, *B*, *C*, *D*, *E*), but the greater number of eggs were left loose in the soil, apparently with no attempt on the part of the beetles to inclose them in a ball of earth. All the earth balls obtained were found in soil that had been fairly well saturated with water. This circumstance would indicate that the particles of which the earth balls are composed are held together only by the cohesive tenacity of the clay, and not by a glutinous secretion of the beetle.

NUMBER DEPOSITED

The number of eggs one female is capable of depositing under natural conditions is difficult to ascertain directly, but some experiments conducted at Charlottesville in 1915 provide data which with a certain degree of reservation may be used as the basis for an estimate. These data indicate that the average deposition for each individual may vary from no eggs to rather more than three a day. Part of this variation may be accounted for by fluctuation of temperature. It has been repeatedly observed that high temperatures favor deposition, while low temperatures retard it. A part of the variation may also be attributed to the disturbance incidental to an examination for eggs.

Usually the average rate of egg production for each individual varies, under particular summer conditions, from 1 egg in every 4 days to 2 eggs a day; and it has been found that a similar range of variation in average daily production occurs if the figures are computed on the basis of a longer period, such as a month (or its equiv-

alent in days), provided that no months later than September are taken into consideration.

From these results it would appear to be a fair inference that on the average each female, under conditions similar to those existing in the experimental cages, is capable of depositing an egg every day during the normal breeding season. If the season lasts between one and two months, a beetle during this period ordinarily may deposit from 30 to 60 eggs.

GROWTH

As previously stated, the egg after deposition enlarges until it is nearly or quite double its original size, and simultaneously changes its form until it is almost globular (Pl. II, *B–E*). Eggs measured at Charlottesville several days after deposition averaged about 2 millimeters in length and 1.5 millimeters in diameter. Unfortunately no measurements of freshly laid eggs were made, but the weights of eggs in different stages of growth were determined with the following results:

In one lot of 15 eggs, all weighed within less than 48 hours after being deposited, a total weight of 0.02013 gram was obtained, an average of 0.001342 gram for each egg. Three days later this same lot weighed 0.04041 gram, an average of 0.002694 for each egg, practically twice the original weight. It was noted that one egg of this lot, on the second weighing, had not increased in size, possibly not having been fertilized, so that the average weight of an egg, at this time, was doubtless somewhat greater than the figures given indicate.

In a second batch of 15 eggs, weighed when they were between 10 and 11 days old, the total weight obtained was 0.05052 gram, an average of 0.003368 gram for each egg, or approximately 2½ times the average of an egg when deposited.

In a third batch, consisting of 9 eggs estimated as 16 days old and nearly ready to hatch and 6 others which were at least 12 days old, the total weight obtained was 0.06538 gram, an average of 0.004359 gram for each egg, or approximately 3½ times the weight of a freshly deposited egg.

No attempt was made to ascertain the cause of this increase in size and weight of the egg by determining its dry weight, but it is doubtless due to the absorption of water by the egg from the surrounding soil. The fact that the dead egg referred to above had not perceptibly increased in bulk after remaining in the soil for three days indicates that only the living eggs are capable of absorbing water.

MOISTURE REQUIREMENTS

It appears evident, as intimated in the preceding section, that the presence of a certain amount of available moisture in the soil is an essential prerequisite for development. The point was tested experimentally at Charlottesville, and it was learned that the eggs perish if kept in dry soil.

It is to be regretted that no quantitative determinations of the moisture requirements of the eggs were made, as these would have been of value in explaining the conditions under which the species

occurs in nature. The experience of the writers, however, both in the field and in experiments, indicates that an excess of moisture is almost as unfavorable for the eggs as a deficiency. The places in which the species normally occurs and in which it breeds most abundantly are so situated with reference to local drainage conditions that, although the ground retains a constant supply of available moisture, it is never saturated with water for any considerable period of time during summer. It is doubtless these moisture requirements which underlie the marked tendency of the species to congregate in the lowlands bordering marshes and drainways and to be limited on the higher ground to local sunken areas in which the soil is rather slowly drained.

INCUBATION

Experiments on the duration of the period of incubation were conducted at Charlottesville. Owing to conditions attending the work, it was rarely possible to determine the precise time at which an egg had been deposited, and, for this reason, the results obtained are at best but approximations. On one occasion (July 26) a female was found in the act of depositing an egg. On August 9 this egg hatched, giving an incubation period of 14 days.

There may be considerable variation in the time required for incubation. This may be accounted for by variations of temperatures, high temperatures accelerating and low ones retarding development. As a rule, the period of incubation under favorable midsummer conditions varies from two to three weeks. In the fall this time is greatly extended, extremes of from 35 to 50 days being reached in October and November. All eggs which had failed to hatch by the middle of November were buried in their containers in the ground and there kept over winter. In early April they were dug up and examined, but in all instances the eggs were dead.

HATCHING

The chitinized larval jaws may be seen through the translucent egg membrane (Pl. II, *D*) several days before hatching takes place. When hatching occurs, the egg membrane appears to collapse and to split at a point close to the dorsal surface of the larva. In one instance the rupture of the membrane occurred in the vicinity of the thoracic region; in another at about the level of the third abdominal segment. It evidently results from the contortions of the inclosed larva in an effort to free itself. After the membrane has split the larva continues its efforts, bending and extending its body at frequent intervals until it has finally managed to extricate itself, though occasionally portions of the membrane may adhere to the larva for a considerable time after hatching. In no instance did the larvæ make any attempt to devour the egg membrane.

The time consumed in the process of hatching was in one instance 7 minutes, in another 35 minutes. Plate II, *F*, shows the newly hatched larva and Figure 3 shows the relative size of the head and body immediately after hatching.

LARVA

DESCRIPTION

The full-grown larva of *Euetheola rugiceps* (fig. 2.) is a robust, thick-bodied grub, with an approximate length of 32 millimeters (1¼ inches) and an average thickness of about 6 millimeters. It is nearly pure white, deepening posteriorly to a dark gray or brownish tint, due to the dark color of the viscera appearing through the transparent cuticle; the legs are yellowish amber; the spiracles orange; the head shield a distinctly reddish hue, closely approximating a bright shade of Indian red. In alcoholic specimens these colors are invariably much obscured.

FIG. 2.—Full-grown larva of *Euetheola rugiceps*. Note relative size of head and trunk. (Drawn by W. R. Walton)

The most distinctive morphological features of the larvæ are found in the head shield and the last ventral segment. The head shield (Pl. III, *A*) is distinctly, even coarsely punctate, the punctures being especially coarse and dense on the portion immediately above the clypeus.

The last ventral segment of the larva (Pl. III, *D*) bears a somewhat irregular, median, double row of modified bristles, each having the appearance of a denticle or minute spine. In the possession of this feature the larva of *Euetheola rugiceps* is unique, so far as the writers are aware, among the Dynastini and agrees with the larvæ of the genera Phyllophaga and Anomala, though in these the corresponding character is much more regular and clearly defined than in Euetheola (Pl. III, *D–G*). In all other respects it resembles the type of larva normal to the Dynastini.

FIG. 3.—Young larva of *Euetheola rugiceps* immediately after hatching. Note relative size of head and trunk, in comparison with Fig. 2. (Drawn by W. R. Walton)

METHODS OF COLLECTING AND REARING

Owing to the pugnacious habits of the larvæ it is best to place each in a separate receptacle when collecting, also to place a little vegetable mold or fine soil in the box to prevent the larva from rolling about and being injured.

Attempts were made to rear the larvæ in flowerpot cages, similar to those used to confine the beetles, but the results were disappointing. The failures were perhaps due, in part, to the fact that suitable food was not supplied the young larvæ when the cages were started, as the food requirements of the young larvæ were then very imperfectly known; possibly, also, to inability to protect the larvæ against certain of their enemies. Ants frequently invaded the cages, and, as they are known to attack and kill the larvæ, were doubtless responsible in some measure for the unsatisfactory results obtained. The

larvæ are often infested with certain mites. which are decidedly injurious to them and frequently cause their death. During the season of 1915 these mites were so abundant and widely distributed that it was found necessary to fumigate all samples of soil used in the breeding boxes.

The salve-box method of rearing larvæ recommended by Davis (*5, p. 138*) gave the best results and proved entirely satisfactory, once the peculiar needs of the young larvæ were ascertained. The principal difficulties were to provide them with an adequate supply of suitable food and to protect them from mites and disease fungi. A few grains of wheat or corn were added to the boxes containing the young larvæ, but the larvæ made no attempt to feed upon either the grain itself or the plantlet issuing from it. Scarcely better results attended the use of the different kinds of manure, either fresh or old and thoroughly weathered. The fine, fibrous rootlets of the corn plant were also tried, but without success. Finally, a satisfactory food was found in a well disintegrated, brownish plant residuum, or vegetable mold, a thin layer of which occurred frequently in an old pasture at Tappahannock, where the species bred abundantly. At first this material was gathered beneath tussocks of the common rush (*Juncus effusus*) where it consisted of the broken and decayed culms of this plant, but subsequently was obtained with much less difficulty in connection with certain grasses belonging to the genus Paspalum and with Japan clover. It was the original intention to utilize this material, owing to its softness, merely as a medium in which the young and tender larvæ might be kept with the least chance of suffering injury. At first a grain or two of wheat was added to each of the boxes containing this material, but it was soon noticed that the wheat was left untouched, whereas the vegetable mold decreased rapidly in amount as the larvæ grew and was replaced by excrement. The wheat kernels were thereafter omitted and finely sifted vegetable mold alone used with entire success.

A larva, after emerging from the egg, was carefully removed to a small tin salve box previously half filled with a quantity of the vegetable mold, finely sifted and slightly moistened. The young larva would invariably burrow into the mold and excavate for itself an irregular cavity, or cell, and there feed upon the surrounding material. When this had been consumed, the larva was temporarily removed from the box, the feces and other wastes cleaned out, and a fresh supply of mold added.

As the larvæ grew, the amount of mold consumed by them increased rapidly, necessitating frequent replenishing. The plan was adopted of substituting for the vegetable mold a kernel or two of corn, previously softened by soaking in water overnight. With larvæ from half-grown to full-grown this proved to be a satisfactory substitute for the mold, and greatly lessened the work of caring for them. Fresh kernels were added only when the old ones had been almost consumed.

Considerable difficulty was experienced in protecting the larvæ from the minute mites previously referred to, specimens of which were identified by Nathan Banks as the hypopus stage of *Rhizoglyphus phylloxerae* Riley. During the season of 1915 this pest was

extremely troublesome, and it required the utmost vigilance to prevent its gaining access to the breeding boxes. According to Mr. Banks, the mites are saprophytic upon decaying vegetable matter, but whatever may be their normal feeding habits, it is the uniform experience of the writers, as well as of others who have worked with white grubs, that the presence of these mites in the breeding boxes is highly detrimental to the larvæ. All soil or vegetable mold for use in breeding boxes was thoroughly fumigated with chloroform to kill all mites. Boxes infested with mites were emptied and sterilized in boiling water. To remove the mites from the larvæ the latter were gently, but firmly, held between the thumb and index finger of the left hand and the mites loosened and brushed off under a binocular by means of forceps. Sometimes, to facilitate the removal of the mites, the larvæ were plunged for an instant into a very weak solution of formaldehyde and then quickly washed in tap water. This treatment appeared to cause the mites to adhere less tenaciously to their host, and also had a quieting effect upon the larva.

For some reason—possibly the prevailing low temperatures of the season—these and other species of mites appeared to be unusually scarce in 1916, so that during that year these precautions were found unnecessary.

FOOD AND FEEDING HABITS

The experience of the writers both in the laboratory and in the field indicates that the normal food of the larvæ consists chiefly of decayed and disintegrated vegetable matter. This vegetable mold does not usually occur as a distinct layer, being intimately intermixed with the surface soil; but in the particular pasture of Tappahannock where most of the collecting was done the mold had accumulated as a practically pure layer on the surface wherever the plant cover was sufficiently dense to protect it from wind and from the trampling of stock. This would be particularly true of old pastures that had not been tilled for a number of years. Vegetable mold of the finest consistency usually occurred under the low, matlike growths of Japan clover (*Lespedeza striata*), wherever these were dense enough to afford it adequate protection. In the layer of vegetable mold, or in the soil immediately underlying it, larvæ of *Euetheola rugiceps* in all stages of growth were found in abundance, particularly where it was associated with clumps of Paspalum, a circumstance that is doubtless connected with the fact that these grasses constitute the usual food of the adults.

In most other localities where the larvæ were found the layer of vegetable mold was not as extensive or as clearly defined as in the pasture at Tappahannock. The favorite haunts of the species appear to be low or poorly drained areas where the plant growth approximates that characteristic of the borders of marshes. In such areas the accumulation of vegetable detritus is relatively rapid.

Attempts were made both at Tappahannock and at Charlottesville to rear the larvæ upon cow manure in various stages of decay. Fresh manure appeared to be highly injurious to them, but old, dry, and well-cured manure, when slightly moistened, proved fairly acceptable, although the mortality among the larvæ fed in this way was excessively high. It would seem probable that, while the vegetable constituents of manure may be suitable for the larvæ, other portions

may be toxic for them. This view is supported by results of field observations, which show that larvæ of this species are only very exceptionally associated with manure. Thus in the old pasture at Tappahannock, where the larvæ were abundant, they were never found beneath the droppings of cattle, although repeated search was made for them in such locations. Furthermore, they were no more frequent in fields that had been treated with manure than in those that had been left untreated. The junior writer has repeatedly searched for the larvæ in fields to which manure had been added earlier in the season, but although the larvæ of certain other scarabaeids, such as *Ligyrus gibbosus* (De G.), *Dyscinetus trachypygus* (Burm.), and *Cotinis nitida* (L.), were unusually common in such fields, those of *Euetheola rugiceps* were either entirely lacking or extremely scarce.

Whether, under natural conditions, the larvæ ever subsist upon living plant material is a question which can not as yet be answered. From the fact that the older larvæ in the breeding experiments were fed with kernels of corn, it would not be unreasonable to suppose that they may feed to some extent upon living plant material. The frequent association of the larvæ with grasses of the genus Paspalum suggests the possibility that they may feed upon the rootlets of these plants, though it is also possible that this association is purely accidental—a result of the parent beetles depositing their eggs in such spots while feeding upon the plants.

Howard (*7*) and Titus (*13*) have inferred that the larvæ feed upon the dead and dying roots of the kinds of cultivated plants—sugar cane and corn—destroyed by the adult beetles. Titus, indeed, goes so far as to offer the suggestion that the object of the beetles in attacking sugar cane is less to secure food than to provide a supply of dead and decaying vegetation for the larvæ to feed upon. So far as corn is concerned, however, there can be little doubt that the beetles attack it primarily for food, and that if the destruction caused thereby is of benefit to the larvæ it must be a very indirect benefit. The junior writer has tested the capacity of the very young larvæ to feed upon dead and decaying corn rootlets, and, while the experiments were not sufficiently extensive to settle the matter fully, the results were entirely negative.

It has been suggested that the larvæ may feed in decaying wood, as do those of some of the near allies of this species. Examination of old logs and stumps at Tappahannock for larvæ of Euetheola yielded only negative results, and it seems reasonably certain that they do not occur in such situations.

In the experiments at Charlottesville an effort was made to rear the larvæ from forest leaf-mold, but, although they appeared to eat this, only a very small proportion of the larvæ tested lived beyond the earliest stages. There is no evidence that the larvæ ever feed upon such material under natural conditions. All attempts to find the species in timbered areas were unsuccessful. It is apparently limited to open situations.

GROWTH

The larva on hatching from the egg is approximately 3 millimeters long; when fully grown the length is about 32 millimeters (1¼ inches). Growth is rapid, the larva attaining full size in from

5 to 8 weeks after hatching—usually this is about a week or 10 days before it is ready to enter the prepupa stage.

DURATION OF THE LARVAL PERIOD

The length of the larval period in the experimental series varied from 44 to 94 days. In the majority of cases, however, it falls between 50 and 65 days, a fair average being about 57 days. Instances in which the duration of this stage was greater than this mostly belong to those larvæ which developed late in the season, when low temperatures retarded their growth.

The earliest date at which larvæ have been found at Tappahannock is June 19. This was in 1916, when a few were hatched from eggs collected in the field on June 5. In the breeding experiments of 1915, larvæ were still being hatched as late as November, but this was evidently abnormal, as there is no evidence that any are ever hatched in the field later than the first part of August. The latest date on which the young larvæ have been found in the field is August 12. This was in 1916, when two were obtained in the old pasture at Tappahannock. The latest date on which full-grown larvæ have been observed in the field is November 2. This also was in 1916, when W. T. Emery recorded finding a few larvæ of what he supposed to be this species in the same pasture. These specimens were unfortunately lost before their specific identity could be fully established. As the early fall of 1916 was unseasonably cold, it is not unlikely that such an extension of the larval period as is indicated by Mr. Emery's observation may have occurred.

Although it is possible that the latest developing larvæ may, in some instances, fail to reach maturity before winter, there is no evidence that any ever survive until the following spring. Both field observations and experiments to test this possibility have given only negative evidence. At Charlottesville the larvæ, each in its own box, were buried in a compost heap on the approach of winter, but when the boxes were dug out and examined in the spring all the larvæ were dead.

MOLTING

Experiments to determine the number of molts and the duration of the periods between molts were made at Charlottesville. Each larva upon hatching was transferred to a salve box, the bottom of which was covered with a disk of moist blotting paper on which were placed a few particles of old cow manure, which had been previously fumigated with chloroform. These experiments were begun August 14, 1915, and were continued throughout the fall and early winter. After September 25 the larvæ were kept indoors, where they were subjected to artificial heat. The mortality in these experiments was high, even after vegetable mold had been substituted for the manure. Consequently only a very small proportion of the larvæ completed their development.

Owing to the late date at which these experiments were begun the time intervals recorded between successive molts can have little significance as regards the duration of these intervals under field conditions.

These experiments showed, however, that the larvæ during their growth pass through two molts. There is, of course, a third molt at the close of the prepupa state. This result is in harmony with those obtained by a number of other workers in Coleoptera.

Immediately after hatching, the head shield of the young larva is distinctly wider than the trunk (fig. 3); at this time it is quite soft and pure white. It hardens, however, within a day or two and assumes the normal red color. It then ceases to grow, but the trunk continues to expand and in time exceeds the head in thickness. Then when the larva has attained considerable size it undergoes its first molt. In the process the skin of the trunk splits lengthwise on the dorsal side, while the head shield becomes detached from it and is forced off the head in front. The new head shield is soft and pure white at first; it expands rapidly after the molt and in a short time hardens, assumes the characteristic red color, and again exceeds the body in width. Succeeding molts are accomplished in the same manner.

The larvæ were frequently observed to devour the exuvium shortly after the molt had been completed.

Table 1 gives data on molting experiments at Charlottesville, Va.

TABLE 1.—*Molting records of Euetheola rugiceps, Charlottesville, Va., 1915*

Serial No.	Larva hatched	First molt	Second molt	Third molt	Emergence of adult
Y1	Aug. 14	Sept. 19	Nov. 4		
Y3		Sept. 15	Oct. 14	Nov. 21	Jan. 6
Y4		Sept. 14	Oct. 12	Nov. 30	Jan. 18
Y7	Aug. 27 (?)	Sept. 20			
Y8	Sept. 1 (?)	Sept. 16			
Y9		Sept. 18	Oct. 18		
Y10		Sept. 21	Oct. 20	Dec. 10	Jan. 18
Y16	Aug. 14	Sept. 16			
Y17		Sept. 21			
Y62	Sept. 25	Oct. 20			
Y63		do			
Y67	Sept. 14	Oct. 19			
Y71		Oct. 14	Nov. 13	Jan. 29	Mar. 9
Y72		Oct. 11	do		
Y73		Oct. 14			
Y74	Sept. 27	Nov. 3			
Y75	Sept. 14	Oct. 18			
Y76		Oct. 21			
Y79			Nov. 19	Jan. 27	

HABITAT

The experience of the writers in Virginia indicates beyond much doubt that the normal habitat of all stages of *Euetheola rugiceps* consists of open grasslands on low or poorly drained areas of relatively heavy, dark-colored soils. The conditions prevailing in the habitat were most fully investigated in the vicinity of Tappahannock, but visits to other points in the State, from which the species has been recorded, show that essentially similar conditions characterize the habitat in all the localities examined.

Similar conditions have also been reported by other writers. Thus Howard (*7*, *p. 12*) quotes a correspondent who wrote from Canton, Miss., that this insect was the worst corn pest on heavy, wet land he had ever experienced. Webster (*14*, *p. 159*) states that in Tensas

Parish, La., and St. Francis County, Ark., corn on clay soils was damaged by the beetles. Sherman (*11*, *p. 44*) records observations of the same character in North Carolina.

In the unpublished records and correspondence of the bureau, additional observations to the same effect are recorded. One correspondent stated that at Dalton, Ga., corn attacked by the beetles was most severely injured in land that had been in meadow and pasture. Another correspondent, of Eutaw, Ala., reported them as doing considerable damage to corn in bottom lands.

Some very interesting observations along the same line have been recorded in his field notes by George G. Ainslie, who investigated an outbreak of the beetles in western Tennessee and Kentucky. In a field at Savannah, Tenn., which he examined, Ainslie observed that the greatest damage to corn was in the lowest part of the field. At Milan, in the same State, he notes that the beetles were most abundant in the lower and moister areas, while at Guthrie, Ky., he found that the greatest injury had been done in a field which adjoined a boggy spot overgrown with large sedges, rushes, and grasses.

While the majority of observers agree in reporting the species as most numerous in heavy, moist soils, Comstock (*3*, *p. 238*), on the contrary, states that in the sugar-cane plantations of Louisiana the injury inflicted by the beetles is confined to those sections in which the soil is of a sandy, friable character, and is lacking in those where it is of a heavy, alluvial type.

In the vicinity of Tappahannock, it was found breeding in a number of more or less scattered stations, each of which was examined with regard to location, type of soil, and character of vegetation. These situations were, without exception, confined to the lower, nearly level lands which border the Rappahannock River and which represent a former flood plain.

One of the breeding grounds most thoroughly studied at Tappahannock was the old pasture frequently mentioned in the foregoing pages, and known as "Coghill's pasture." This pasture included about 20 acres, the greater part of which consisted of a rather heavy clay loam of a dark gray or slate color, and was about 2 miles back from the river. It had not been cultivated for at least 25 years and undoubtedly was of a marshy or swampy nature formerly, being considerably lower than surrounding cultivated fields. Many of the lower spots of this pasture had a thick cover of grasses under which was a thin layer of vegetable mold, where, as previously stated, many larvæ of *Euetheola rugiceps* were found.

The vegetation covering this tract was chiefly composed of species of grasses and sedges, the most abundant of which were those belonging to the following genera: Panicum, Paspalum, and Fimbristylis. There were heavy growths of Japan clover (*Lespedeza striata*) in places; in the moistest spots were numerous tussocks of the tall rush (*Juncus effusus*).

A second pasture about 2 miles southeast of Tappahannock resembled Coghill's pasture in all essential respects. It joined a woodland locally known as White Oak Swamp, and was really reclaimed swamp, so the junior writer was informed. Larvæ were plentiful here, also, under the heavy growths of *Paspalum laeve*.

A third breeding ground was in a pasture close to the Rappahannock River, bordering a tidal marsh. This pasture was quite low,

its highest point probably not exceeding 4 feet above tide, from which point it sloped gently toward the marsh. Most of the larvæ of *Euetheola rugiceps* were found within a few yards of the marsh under growths of *Paspalum laeve*, the soil at that point being moist but not soggy. The soil and vegetation here were essentially similar to those in the Coghill pasture.

Larvæ of *Euetheola rugiceps* were found in a number of other locations near Tappahannock and wherever found in numbers the locations were similar in all essential respects to the pastures previously described.

Besides occurring in what may be considered their normal habitat, larvæ have been found in locations that are not entirely typical. Such occurrences seem very localized and are restricted to areas near the normal breeding grounds. Also, larvæ seem rarely to reach maturity in well-cultivated fields. For example, in cornfields near old breeding grounds, and in which the corn was practically destroyed, very few full-grown larvæ could be found.

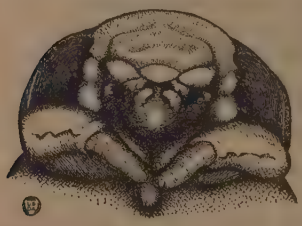


FIG. 4.—Ventral view of head region of pupa of *Euetheola rugiceps*, showing structure of mouth parts. (Drawn by Henry Fox from photograph by J. H. Paine)

The junior writer carefully examined a hay field for larvæ, the sod consisting chiefly of timothy, clover, and Bermuda grass. This field was near the Coghill pasture and had been in sod only three or four years. Across one end, in an area about 20 feet square, a large number of larvæ of *Euetheola rugiceps* were found, while elsewhere in the field the larvæ appeared very scarce. There seems to be no satisfactory explanation of this singular occurrence at present. The field just mentioned was planted to corn the following year and there was considerable injury from *E. rugiceps*, the greater part of the injury being in the vicinity of the spot where the larvæ were so plentiful the preceding year. This does not prove conclusively, however, that a good part of the injury was not due to migrating beetles from the old pasture.

The soil in the timothy sod of the field just mentioned was a fine, rather sandy loam. Fine sandy loams appear to constitute the dominant types throughout most of the region bordering the Rappahannock River. These soils apparently harbor *Euetheola rugiceps* only in the poorly drained areas that have become overgrown with wild grasses. In the opinion of the writers thorough cultivation combined with good drainage will eliminate *E. rugiceps* as a corn pest in such localities.

PREPUPA

In the beginning of the prepupa stage the larva ceases to feed and becomes relatively quiescent, the power of movement being retained only within the posterior half, which is capable of being bent forward beneath the thorax and then straightened out again. This movement may be repeated a number of times in rapid succession and is doubtless of use in assisting the creature to enlarge the cavity or cell in which the pupa stage is passed, as well as in splitting the larval integument and thereby freeing the inclosed pupa. During the pre-

pupa stage the larva lies on its back, in a slightly curved position, in the cavity formed by its movement in the soil. While still inclosed in the old integument, the larva undergoes its transformation into a pupa. This process is initiated by the withdrawal of the internal mass of the body from the larval integument at its hind end, which becomes greatly shriveled. Finally, when the pupal body has been formed, the larval skin splits along the dorsal line, revealing the fully formed pupa within. The latter frequently passes its entire existence inclosed within the split larval skin.

FIG. 5.—Ventral view of posterior end of abdomen of male pupa of *Euetheola rugiceps*, showing sexual characters. (Drawn by Henry Fox)

PUPA

DESCRIPTION

The pupa of *Euetheola rugiceps* measures on the average about 15 millimeters in length, and is pale buff. Its general form is shown in Plate IV, *A*, and certain of its structural features in Figures 4, 5, and 6, but probably its most distinctive peculiarities are those of the mouth parts (fig. 4). The mandibles are relatively stout, roughly triangular in outline, and with the apex forming a rounded angle. The labrum is quite wide transversely, and has its free edges regularly and evenly arcuate. The maxillary palpi are short, conical structures which are nearly vertical in position and have their tips projecting but slightly below the level occupied by the other mouth parts.

FIG. 6.—Ventral view of posterior end of abdomen of female pupa of *Euetheola rugiceps*, showing sexual characters. (Drawn by Henry Fox)

Other distinctive characters are afforded by the shape of the postcoxal process of the prosternum, which is rather short, blunt, and constricted near the middle, and by the elytral pads, which are smooth, or, at most, only obscurely costate.

Sexual characters in the pupa occur in the ventral surface of the last abdominal segment. In the male this bears a prominent hemispheric protuberance, the apex of which is slightly indented (fig. 5); in the female this structure is lacking, but instead there is a minute median projection of the anterior border of this segment into the segment in front (fig. 6). This process shows a pair of lateral, more fully chitinized areas which probably correspond to the genital plate of the adult female.

DURATION OF THE PUPA STAGE

The pupa stage may last from 9 to 44 days, but usually falls between 10 and 19 days, so that two weeks may be said to be a fair average period for the duration of the stage under normal conditions. The precise length of this period unquestionably is determined by the prevailing temperatures. Instances in which the length of the stage is much in excess of the normal pertain to individuals which have undergone their development late in the season.

The earliest date on which pupæ have been obtained at Tappahannock is July 31, when there appeared in one of the breeding boxes a pupa which had developed from a larva collected at the same locality on June 30. The earliest record of actually finding pupæ in the field is August 12. They appear to be most abundant during the last part of August and first half of September. Pupæ have been found in the field as late as November and it seems quite probable that a small

FIG. 7.—*Euetheola rugiceps:* Adult. (Drawn by Henry Fox)

FIG. 8.—Ventral view of adult *Euetheola rugiceps*, showing structural characters. (Drawn by Henry Fox)

number may fail to mature before winter. There is no evidence that such pupæ ever survive until the following spring, as all the pupæ in the possession of the writers buried in the ground at Charlottesville perished during the winter.

ADULT

DESCRIPTION

The adult of *Euetheola rugiceps* (Pl. I, *B;* II, *A;* figs. 7, 8) is a rather stout, jet black beetle, having an average length in Virginia and Tennessee material of from 13 to 16 millimeters. The surface in recently emerged individuals is highly polished,[5] but is dull and opaque in old and worn ones.

[5] Casey (*1, p. 187*) in his recent memoirs asserts that the body is "not very shining," and gives this as one of the characters distinguishing *Euetheola rugiceps* from another form from Honduras, which he describes as a new species, *hondurana*. The writers are inclined to think from Casey's description that he had at hand only old individuals of *rugiceps*, doubtless collected during the spring, as the younger ones, collected in the fall, are almost invariably rather highly polished and of an intense black color.

The head is rather short, its median length being about half its maximum width. Its surface is marked by numerous transverse, undulate rugulæ (fig. 8) which are reduced to minute granulations on the front half of the clypeus and disappear on the occiput, which is quite smooth, except for a few sparse, shallow punctures. The clypeus has strongly oblique sides which are conspicuously margined and elevated. Immediately in front of the clypeal suture the head is crossed by a rather low, transverse ridge, or carina, which is broadly interrupted in the middle. The apical margin of the clypeus is almost truncate and rather short, being only about one-fourth the width of the base. It is dorsally reflexed and crested, the crest being interrupted in the middle by an oblique sinus, which separates the two conical processes—the so-called "teeth"—arising from the crest. These "teeth" in fresh specimens are rather high and sharp, but in old and worn specimens are frequently reduced to mere stumps. The mandibles are visible from above beyond the sides of the clypeus, and are very unequally bidentate, the anterior tooth, which is upturned at the apex, being much larger than the short, obtuse, posterior one.

The pronotum is distinctly wider than long, and about twice as wide as the head. Its sides are broadly and evenly arcuate and narrowed slightly anteriorly, the surface being smoothly and uniformly convex, bearing numerous coarse, annular punctures which are somewhat sparsely distributed throughout but rather more crowded on the sides than in the middle. The anterior and lateral borders are clearly margined, the posterior plain and feebly bisinuate. The antero-lateral angles are sharply produced anteriorly, while the postero-lateral ones are broadly rounded and obtuse-angulate.

The scutellum, although rather small, is quite distinct, the surface being smooth, except for a few minute punctures.

The elytra are but slightly longer than their combined width, which is not obviously greater than that of the pronotum. Each is longitudinally traversed by a number of slightly impressed, double rows of rather coarse, circular punctures, these giving the elytra a somewhat striate appearance (fig. 7). Anteriorly these punctures are frequently confluent and variolate. Outside of the double rows of punctures, the entire surface of the elytra is covered with numerous closely set and irregularly distributed punctures, which, for the most part, are essentially similar to those forming the double rows, but are reduced on the sides and apical half to minute, punctate impressions.

The stridulating organs on the inner surface of the elytra are very feebly developed.

The labium (fig. 8) is considerably longer than wide, and is appreciably narrowed at its apical end, which is feebly bilobed and marked by sharply elevated lateral margins situated under the insertion of the palpi; the basal half is rather strongly convex, without lateral margins, and bears on the sides numerous long stiff bristles, which are largely lacking toward the center.

The prosternum (fig. 8) bears a stout, erect, cylindrical, postcoxal process or spine, the apex of which is almost flat and occupied by a smooth, padlike surface, the hind margin of which bears a conspicuous, radiating fringe of long, stiff bristles.

The surface of the mesosternum and metasternum is nearly smooth, or at most but very sparsely and indistinctly pilose. The metasternum bears numerous shallow, circular punctures, larger and coarser on the side than in the middle, each of which is frequently provided with a minute, barely visible bristle or seta. The mesepisternum has its surface somewhat rugulose and bears a rather sparse covering of stiff hairs.

The forelegs are relatively stout and are adapted for digging. The tibiæ bear on the hind margin four distinct, toothlike projections, three being long, stout, and acute; the fourth, or uppermost, much smaller and decidedly obtuse.

SEXUAL CHARACTERS

The last ventral segment of the male (fig. 9) bears near the anal margin a transverse fringe of short, stiff hairs which is broadly interrupted in the middle; back of this interruption or hairless interval there is a short postanal fringe. In the female (fig. 10) the same character is also present, but there is no median break, the fringe being continuous.

A less obvious difference between the sexes is, as pointed out by Casey, in the form of the pygidium, which is slightly shorter, more convex, and more broadly rounded at the apex in the male than in the female.

The male claspers (fig. 11) are symmetrical, each consisting of a vertical flange resembling that of *Ligyrus gibbosus* (fig. 12) but considerably smaller and slenderer and with the upturned process on its postero-lateral face more nearly basal, toothlike, and extending obliquely backward. The female genitalia consist of two pairs of almost flat plates—a large superior and a small inferior pair, the latter fringed apically with short hairs. A pubic process is lacking.

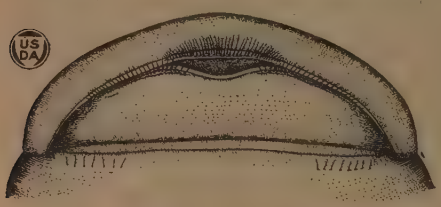


FIG. 9.—Ventral view of tip of abdomen of adult male *Euetheola rugiceps*, showing structural characters. (Drawn by Henry Fox)

TIME OF EMERGENCE

The earliest date on which adults of the newly emerged generation have been observed under laboratory conditions at Tappahannock is August 13. This was in 1915, when an adult, reared from a larva collected June 30, appeared in one of the breeding boxes. The earliest date on which adults have been found in the field is August 24 (in 1915 and 1916).

The period of emergence extends throughout the last part of August and the whole of September and October, although ordinarily relatively few appear to emerge later than the end of September. The latest emergence of which there is record is of two individuals which developed in the breeding boxes early in November. In 1915 the majority of the beetles emerged between September 1 and September 25, the period between September 10 and September 20 being especially prolific in emergences.

FIG. 10.—Ventral view of tip of abdomen of adult female *Euetheola rugiceps*, showing structural characters. (Drawn by Henry Fox)

COLOR CHANGES

When the adults emerge from the pupa they differ greatly in color from the typical mature beetles. The earliest changes in color take place during the closing days of pupal existence, while the adult is still inclosed within the pupal integument. These changes involve only the head and thorax, which at the time of emergence are already well chitinized and bright orange red. The elytra, however, at this time are quite soft and colorless, but assume a pale creamy hue within an hour or two, also becoming perceptibly firmer; in a few hours more this changes to a bright orange. The following day, under normal conditions, the color of the elytra gradually grows darker, becoming a vermilion red or Indian red. In the meantime the head and thorax have been changing color

rapidly and have become considerably darker than the elytra and are a deep purplish red. The elytra soon acquire the same shade. The final stage naturally is the transformation of this color into the deep black of the typical beetle.

Under favorable conditions these color changes are completed in from four to five days, but in cooler weather the time required to effect them may be greatly extended. Thus, in October and November, beetles were frequently found to retain their red coloration for a period of two or three weeks.

FIG. 11.—Lateral view of male clasper of *Euetheola rugiceps*. (Drawn by Henry Fox)

ACTIVITY IN THE FALL

The adults appear to be much less active in the fall than in the spring. So far as the writers are aware, there are no records of the beetles having been taken at lights during this season. At Tappahannock, in the fall of 1915, they were frequently observed on or immediately under the surface in the places where they had emerged. Almost invariably they were to be found beneath clumps of their favorite food plants, *Paspalum* spp., boring into and cutting off the culms of these grasses. The junior writer never observed any of the beetles outside of their natural habitat at this time of the year, but W. T. Emery, who visited the breeding grounds of the species at Tappahannock in early November of 1916, reported that he had seen a small number crawling on an adjoining highway. Mr. Emery states that the day on which these beetles were observed was unusually warm and mild, a circumstance which doubtless accounts for their wandering abroad.

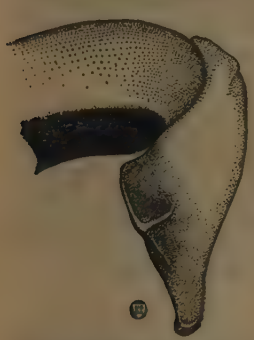


FIG. 12.—Lateral view of male clasper of *Ligyrus gibbosus*. (Drawn by Henry Fox)

HIBERNATION

No systematic observations on the hibernation of the beetles were made. So far as the available evidence goes, it indicates that hibernation takes place in the normal feeding ground of the species and in much the same manner as in other scarabaeids which pass the winter in the adult stage. On one occasion during the plowing of a timothy pasture at Tappahannock in February of 1916, the junior writer picked up a few beetles of this species. The depth at which they occurred could not have exceeded 8 inches and was probably less. From the fact that some larvæ reach maturity in cultivated fields, it is probable that many hibernate there, but they are insignificant in comparison with the much greater numbers that hibernate and emerge in the normal habitat of the species.

Experience with beetles kept in cages outdoors, during the winter of 1915–16, indicates a heavy mortality among the hibernating beetles during this season in the latitude of Virginia. At both Charlottesville and Tappahannock only about a third of all the

beetles placed in the hibernating cages in the fall were living when the cages were examined in the spring. That an equally heavy mortality may obtain under natural conditions is indicated by the fact that where the beetles had been quite abundant in the fall of 1915, only a few could be found in the following spring. Doubtless if the species could be kept under constant observation for a succession of years, it would be found that winter conditions constitute one of the important factors controlling the destructive outbreaks of the species which seem to occur at rather long intervals.

APPEARANCE IN SPRING

The beetles usually begin to emerge from their hibernating quarters in the spring in late April or in early May, except in the most southern portions of its range. The precise time of emergence is governed by prevailing weather conditions. Comstock (*3*) states that they become active as early as the middle of March in Louisiana. At Tappahanock the earliest dates on which they have been seen abroad were April 23 in 1915 and May 1 in 1916. At Clarksville, Tenn., the junior writer first observed them at street lamps on April 18, 1917. McConnell recorded them (unpublished notes) as active and destructive at Greenwood, Miss., on April 23, 1913. Webster (*14*) reported them damaging corn in Louisiana on April 25, 1888. Becker informed the junior writer that complaints of injury by the beetles came in from southern Arkansas about May 1.

MATING

Mating of *Euetheola rugiceps* is practically coextensive with the period of its maximum activity. The earliest date on which the beetles were observed *in coitu* was May 13, 1915, at Sharps, Va., while the latest date on which they were observed mating under natural conditions was June 20, 1915, at Tappahannock. In the case of those kept in breeding cages, mating was observed much later than this, one pair being observed *in coitu* as late as September 10. Mating normally takes place underground, though on one occasion a pair were found *in coitu* on the surface in a slight hollow at the base of a cornstalk; they were also found mating in tin boxes in which they were placed during collection. It seemed to be immaterial to the beetles whether soil was in the boxes or not.

OVIPOSITION

Oviposition was observed to occur at Tappahannock chiefly during June, the earliest eggs being found on June 5. It would seem probable that eggs may be deposited during July, but the writers have no records of obtaining any during that month. Most of the eggs are apparently deposited during the last half of June. Beetles kept in cages under somewhat artificial conditions continued oviposition, except for temporary interruptions due to the inclement weather, throughout the summer, and until as late as the last of September; a small number of eggs even being deposited in October and in early November. In nature, however, such prolongation of the breeding season evidently does not occur, as field experience indicates beyond a reasonable doubt that practically all the beetles

of the egg-laying generation of the year have perished by the first of August.

At Tappahannock, eggs, or recently hatched larvæ, were found in hills of corn and in a layer of vegetable mold. In this vegetable mold they were often deposited at the base of tussocks of the common rush, beneath clumps of pasture grasses, especially those of the genus Paspalum, and under low mats of Japan clover. The eggs hatch within two or three weeks under normal summer conditions.

ACTIVITY IN THE SPRING

The beetles are unquestionably much more active and attract far more attention in the spring than during the fall. This is due doubtless to the activities connected with feeding and reproduction. The beetles are rather sluggish, and if their needs are adequately met they apparently do not roam much. When, from any cause, their needs are not satisfied, they may come out of the ground and go elsewhere in search of more favorable locations, either by flight or by crawling away on the surface. Apparently the beetles fly only at night, when they are frequently attracted to lights, but the junior writer has repeatedly observed them crawling on the surface in bright daylight.

From observations made on caged individuals, it would appear that the impulse to wander may come from lack of food as well as from the instinct to mate. Thus, in cages in which beetles were confined without food, they often came out on the surface, especially at night, and crawled up the sides of the cages, frequently attempting to take flight; whereas in adjoining cages, in which the inmates were plentifully supplied with food, it was a rare event for one to be found on the surface at any time. A beetle has occasionally been observed to emerge from a hill of corn in which all the plants had been killed and move off to another where the plants were intact.

FOOD PLANTS AND CHARACTER OF INJURY BY THE BEETLE

Euetheola rugiceps is best known as an enemy of corn and sugar cane, but there is reason to believe that these are not its normal food plants. During the fall of 1915 the junior writer found them feeding abundantly upon certain species of grasses belonging to the genus Paspalum. These grasses have since been found in every section visited by him in which the species has been found or from which it has been reported, and there is accordingly every reason to believe that they constitute the favorite food of the beetles. Beetles kept in confinement ate the plants eagerly. At Tappahannock the species of Paspalum fed upon were determined as *P. laeve* and *P. plenipilum*. The large, coarse-stemmed forms, such as *P. floridanum*, do not appear to be acceptable to them. The beetles attack these grasses in much the same manner as they do corn, forcing their way beneath the tufts, or coming up under them from below, and boring into the culms where the latter lie in contact with the ground. Sometimes the culms are cut completely off, but even when they are not entirely severed such a thin and broken bit of tissue is left connecting the parts that the portion beyond the injury quickly wilts and dies. In the fall of 1915 it was a common occurrence to find large patches of Paspalum which had been almost or quite completely destroyed by them.

The beetles also feed upon the common rush (*Juncus effusus*). The culms of this plant form a dense tuft and are extremely tough and dry, except at the base, where they are somewhat tender. The beetles attack and cut them off at that point. Owing to the crowded condition of the culms at the base of the plant, it was not possible to detect the beetles at work, but they were found lying motionless in such situations and beside the broken and shredded culms. Tufts of the rush, from which all imperfect culms had been carefully removed, were transplanted to a cage containing the beetles and, when examined several days later, were found to have a considerable number of their culms broken off and shredded in the same manner as those observed in the field. It would appear, however, that the beetles prefer the Paspalum grasses to the rush.

Bermuda grass (*Capriola dactylon*) also is probably eaten by the beetles, though very much less readily than Paspalum. This grass occurs practically everywhere throughout the entire coastal section of Virginia and is especially characteristic of the better cultivated areas. It abounds in many situations in which Paspalum is scarce or lacking. Indeed, it would seem that the chief danger of *Euetheola rugiceps* perpetuating itself in farming districts and other places outside its typical habitat lies in the universal presence of this grass and the apparent ability of the pest to utilize it as food when no other is available. One would imagine that the hard and wiry stolons of Bermuda grass would scarcely prove very attractive; nevertheless the junior writer has repeatedly found them torn and frayed in the manner characteristic of injury by this species. Similar injury has also been caused by planting the stolons in a cage containing the beetles.

Corn is attacked by the beetles only in the spring and early summer when it is young. Later in the season the stalks become too hard for them to penetrate. The plants may be attacked as soon as they appear above ground, and are not safe from serious injury until they are fully waist high. The beetles are particularly fond of the apical growing point of the stalk, the so-called "heart," which is the most vital and important part of the plant. In the early stages of growth of the corn plant this structure forms a minute conical bud, situated below the surface of the ground in the center of the stalk. To reach this part the beetle bores into the stalk at any point between the surface of the ground and the point of attachment of the roots, making a large, ragged opening (Pl. I, *B*). The work of the beetle is indicated above ground by wilting of the inner set of leaves, the outer ones retaining their rigidity for a considerable period after the other leaves have died.

In a somewhat later stage of growth, after the stalk proper has begun to elongate and has carried the terminal bud well above ground level, the injury done by the beetle boring into the stalk is usually less severe, only a more or less extensive part of the pith at this time being destroyed, the more vital growing part being out of reach of the beetles. At this time the stalk is also considerably thicker than before, and a beetle may finish feeding before it has destroyed enough of the vascular supply of the plant to interfere seriously with its functions.

The chief danger to larger corn plants is naturally in the weakening of the stalk, which may result in its being blown over or broken

off by strong winds. Plate I, *A*, represents a badly injured cornfield in the vicinity of Tappahannock. This field had been replanted several times. There were a number of fields showing such injury in the vicinity of Tappahannock.

An interesting discovery in relation to the feeding habits of *Euetheola rugiceps* is that it will feed readily on apples, either in breeding cages or in the field. This fact was first ascertained by Ezra Shackelford, at Tappahannock, who informed the junior writer that he had found a beetle feeding on a fallen apple in the orchard. This observation subsequently was verified.

All efforts to find the beetles feeding under natural conditions on common grasses other than *Paspalum* spp., and Bermuda grass were futile, though in breeding cages they were induced to accept *Panicum lindheimeri* and *Fimbristylis baldwiniana*. The indications, however, are that the beetles do not like these plants, and that they feed upon them only when deprived of all other food.

Since ironweed (*Vernonia noveboracensis*) was a common weed in the typical habitat of the species, an experiment was made to ascertain if the beetles were capable of utilizing it for food. The results were entirely negative. The junior writer found that the common ragweed (*Ambrosia artemisiaefolia*), the well-known food plant of *Ligyrus gibbosus*, was unacceptable to *E. rugiceps* in breeding cages, nor could they ever be found attacking these plants in the field.

One or two correspondents of the Bureau of Entomology have stated that potatoes are occasionally injured by *Euetheola rugiceps*. To test this point, the junior writer on one occasion buried a few tubers in a cage containing a considerable number of beetles, but the latter apparently took no notice of them.

At Tappahannock *Euetheola rugiceps* could never be found attacking the common grass locally known as goose-grass (*Eleusine indica*), but to ascertain if the beetles are capable of subsisting on it a quantity was transplanted to one of the cages containing the beetles. When examined a week later it was found that a number of the culms had been shredded to some extent at the base, but that in only a few was the injury serious. Evidently the beetles do not willingly feed upon this grass, but may possibly do so to a slight extent if unable to obtain more acceptable food.

Since the beetles were found to be rather common in one of the timothy-clover pastures at Tappahannock, tests were made to ascertain if the beetles would feed upon these plants. In both instances they were untouched. It is probable, therefore, that beetles living in timothy and clover fields derive their sustenance from some other plant associated with them. This, in all likelihood, is Bermuda grass, which is usually common in such fields.

Occasionally the adults are accused of damaging rice. The writers have never had an opportunity to study the species in rice-growing sections and are unable to speak on this matter from personal observation. Inasmuch as *Euetheola rugiceps* in one or two instances was reported as injuring rice, and subsequently proved to be the allied species *Dyscinetus trachypygus*, the writers can not avoid the suspicion that all other reports of such injury may be cases of mistakes in identification. Superficially the adults of the two species are much alike and may be easily confused by persons not familiar with their distinctive characters.

DURATION OF THE ADULT STAGE

The writers have stated that the adults of the overwintering generation of *Euetheola rugiceps* perish, under natural conditions, by midsummer. In the experimental cages numerous beetles of this generation not only survived the summer but in some instances lived until late in the fall. This late survival possibly was due to the protection which the beetles received from the extremes of heat and dryness to which in nature they are exposed. A heavy mortality among the beetles immediately after the mating season is evidenced not only by the large numbers of dead beetles found in the field at that time but also by the fact that corn planted late in the season—after June 1—is almost invariably much less severely damaged than that planted earlier. The longevity of adults in the breeding cages was undoubtedly due to the better care they received, as other adults, confined in similar cages but left exposed in the open to as nearly natural conditions as possible, perished in midsummer within a few weeks after the cages were started.

This view is supported by the testimony of others who have had experience with this species. Howard (*7*) mentions a correspondent at Canton, Miss., who reported that previous to July 9 he had had little difficulty in finding the adults, but after a week of dry weather they had entirely disappeared. Sherman (*11*) also quotes a correspondent who, writing on June 14, reported that, although the beetles had been very numerous and destructive in his cornfields, he had noticed that within the last few days the dead beetles could be seen all about the field. He added that his corn crop had been so completely destroyed that the field was plowed up on June 1 and a new crop planted a week later but that this second crop remained uninjured.

Apparently the duration of the adult stage in the latitude of Virginia is from 9 to 11 months. The results obtained in experiments indicate that under exceptional conditions in nature the adult stage may conceivably last from a year to 14 months.

SPECIES LIKELY TO BE MISTAKEN FOR EUETHEOLA RUGICEPS

Euetheola rugiceps is often associated with other species of scarabaeid beetles which may be easily confused with it. Its most constant associates are its close allies, *Ligyrus gibbosus* (De Geer) and *Dyscinetus trachypygus* (Burm.). For this reason these two species will be considered in somewhat greater detail than the remaining forms.

LIGYRUS GIBBOSUS (De Geer)

The life history of *Ligyrus gibbosus* is essentially the same as that of *Euetheola rugiceps*. The larvæ of *L. gibbosus* develop more rapidly, consequently the adults of the new generation appear earlier in the fall than those of *Euetheola rugiceps*. The writers have never found *L. gibbosus* injuring corn in the field, nor could it be induced to feed upon corn in breeding cages.

LARVA

In general form, size, and coloration the larva of *L. gibbosus* resembles that of *E. rugiceps*. As in the latter the fully chitinized

head is of a distinctly reddish color but, unlike *E. rugiceps*, the head is smooth or at most but slightly rugulose, lacking almost entirely the deep punctures which are so conspicuous in the latter species. (Pl. III, *A* and *B*.) Furthermore, in the larva of *L. gibbosus* there is no trace of a median double row of modified bristles on the last ventral segment, such as occurs in *E. rugiceps*. (Pl. III, *D* and *E*.)

PUPA

FIG. 13.—Ventral view of head region of pupa of *Ligyrus gibbosus*, showing structure of mouth parts. (Drawn by Henry Fox from a photograph by J. H. Paine)

The pupa of *L. gibbosus* (Pl. IV, *B*) is distinguished from that of *E. rugiceps* by certain characters associated with the mouth parts, by the form and position of the posteoxal process of the prosternum, and by the prominent bicostate elytral pads (Pl. IV, *A* and *B*, and figs. 4 and 13). The mandibles (fig. 13) are much smaller and slenderer than those of *E. rugiceps*, and are further characterized by the truncate, not angulate, apex which lies in contact with the nearly straight sides of the labrum. The maxillary palpi are also shorter and rather more rounded at the apex than in *E. rugiceps*. The posteoxal process of the prosternum is less nearly erect and the apex is rather more acuminate than in *E. rugiceps*.

FIG. 14.—*Ligyrus gibbosus*: Adult. (Drawn by Henry Fox)

ADULT

In general form and size the adult of *L. gibbosus* (fig. 14) resembles that of *E. rugiceps*, but is usually distinguishable at a glance by its reddish brown color and by the distinctly hirsute character of its ventral surface. Occasionally adults are found in which the color is so dark as to be almost black. The most reliable differential character is the presence in *L. gibbosus* of a median pit or depression close to the anterior margin of the pronotum, which is entirely lacking in *E. rugiceps*. In front of this pit is a blunt spine or tubercle. Other distinguishing characters of *L. gibbosus* are the absence of transverse rugulæ and the presence of a continuous transverse ridge on the dorsal surface of the head.

The stridulating areas on the inner surface of the elytra are well developed in *L. gibbosus* and are capable of producing a low but audible sound, which is usually heard whenever the beetles are handled. In *E. rugiceps* the stridulating area is barely recognizable and is apparently functionless.

DYSCINETUS TRACHYPYGUS (Burm.)

The life history of *Dyscinetus trachypygus* agrees very closely with that of *Euetheola rugiceps*. Development takes place at about the same rate in both species. Both may occur in similar situations, though *D. trachypygus* appears to be more tolerant of the products of organic putrefaction. Thus it has been taken in both adult and larval stages in compost heaps and in the vicinity of pigpens, situations in which *E. rugiceps* has thus far never been found. There is no evidence that the adults of this species ever injure corn, as all experiments made to test this possibility yielded only negative results. Farther south they attack rice, and for that reason the species has been given the popular name of "rice beetle."

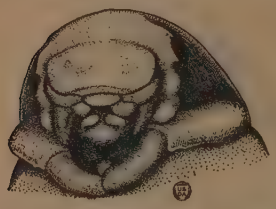


FIG. 15.—Ventral view of head region of pupa of *Dyscinetus trachypygus*. (Drawn by Henry Fox)

LARVA

The larva differs from that of *E. rugiceps* mainly in the entire absence of anything suggestive of a median double row of modified bristles on the last ventral segment (Pl. III, *F*). The surface of the front of the head is sculptured as in *E. rugiceps* (Pl. III, *A* and *C*).

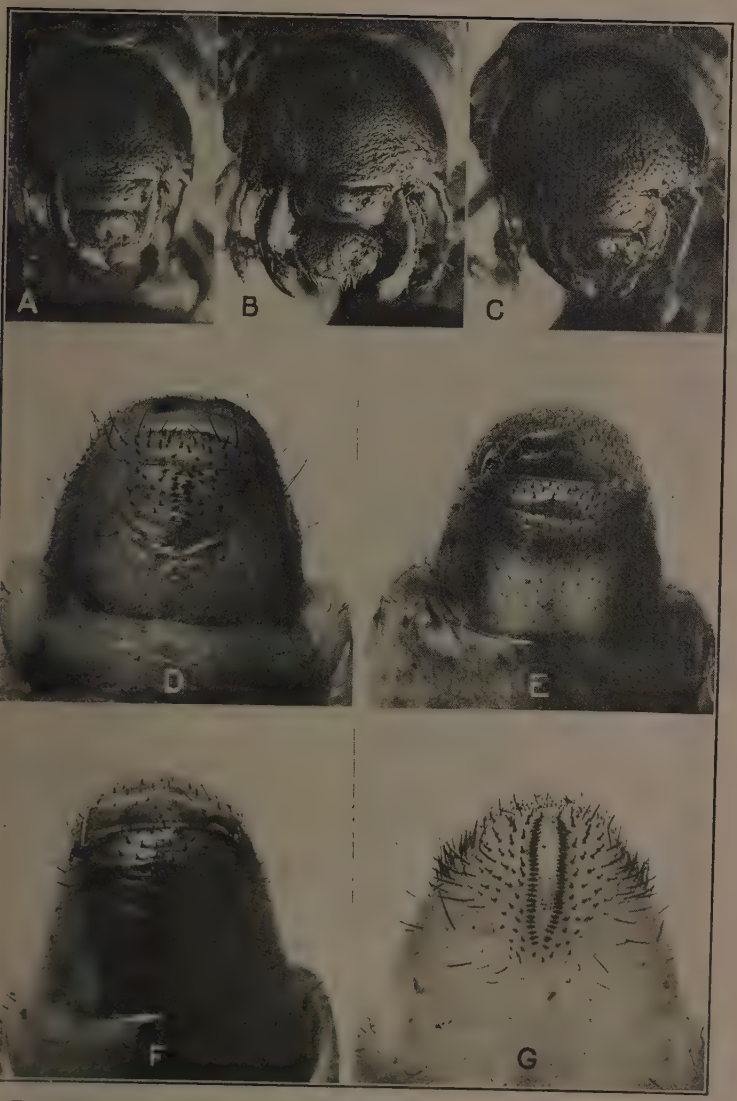
PUPA

The pupa of *D. trachypygus* (Pl. IV, *C*) is readily distinguished from that of *E. rugiceps* by its longer and smoother head and by the form of the mouth parts. The mandibles are much longer and more slender than in either *E. rugiceps* or *L. gibbosus*, and terminate in a short, nearly truncate apex which lies in contact with the sides of the relatively small labrum (fig. 15). The maxillary palpi are unusually elongate, with an acute apex, and project considerably beyond the general level of the other mouth parts. The postcoxal process of the prosternum is more nearly oblique and rather more blunt than in *E. rugiceps*.

FIG. 16.—*Dyscinetus trachypygus:* Adult. (Drawn by Henry Fox)

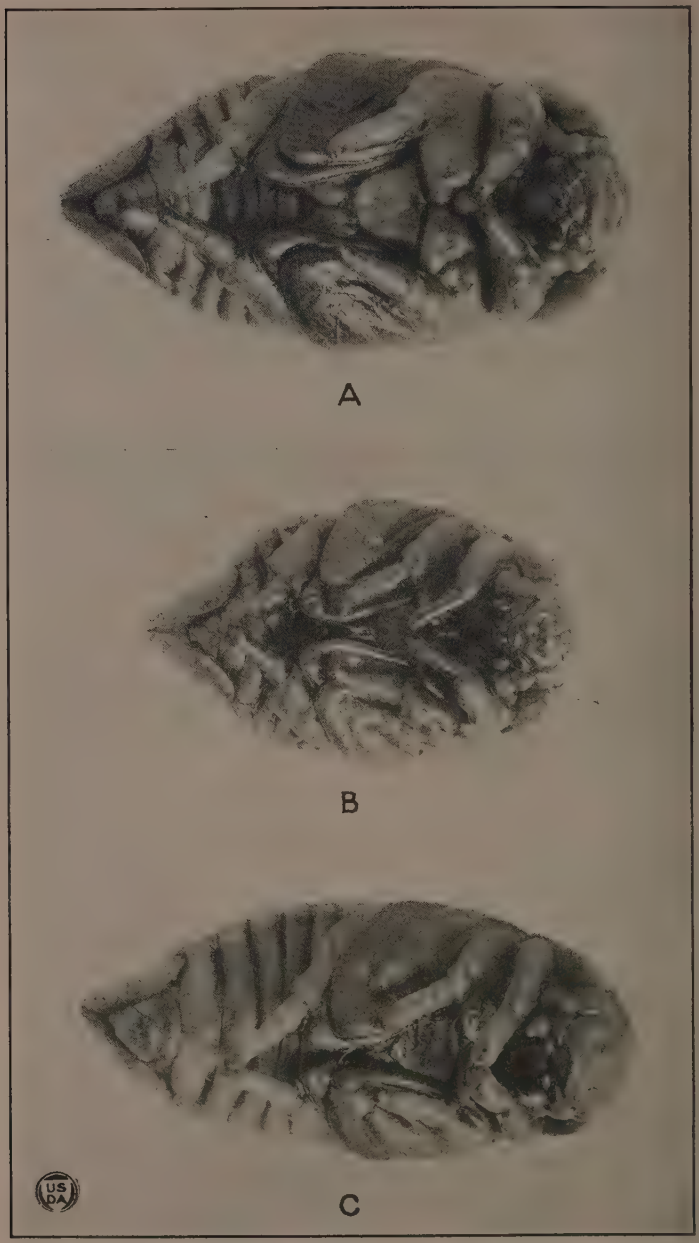
ADULT

D. trachypygus (fig. 16) may be readily recognized by its toothless mandibles and by the form and smoothness of the head. The latter is both longer and wider than in either Euetheola or Ligyrus



THE ROUGH-HEADED CORN STALK-BEETLE AND SPECIES LIKELY TO BE MISTAKEN FOR IT

A, Frontal view of head of larva of *Euetheola rugiceps*, showing the strongly punctate surface; *B*, frontal view of head of larva of *Ligyrus gibbosus*, showing its relatively smooth surface; *C*, frontal view of head of larva of *Dyscinetus trachypygus*, showing its strongly punctate surface; *D*, ventral view of anal region of larva of *E. rugiceps*, showing median double row of modified bristles on last segment; *E*, ventral view of anal region of larva of *D. gibbosus* (note absence of any trace of a median double row of modified bristles on last segment); *F*, ventral view of anal region of larva of *D. trachypygus* (note entire absence of a median double row of modified bristles and relative coarseness of bristles); *G*, ventral view of anal region of larva of *Phyllophaga* sp., showing sharply differentiated median double row of modified bristles on last ventral segment. (Photographs by J. H. Paine)



THE ROUGH-HEADED CORN STALK-BEETLE AND SPECIES LIKELY TO BE MISTAKEN FOR IT

A, Pupa of *Euetheola rugiceps*; *B*, pupa of *Ligyrus gibbosus*; *C*, pupa of *Dyscinetus trachypygus*. (Photographs by J. H. Paine)

and is characterized by its large, nearly rectangular clypeus which is separated from the epicranium by a distinct clypeal suture. The surface of the head is smooth except for a number of rather sparse punctures and is entirely devoid of either rugulæ or a transverse ridge.

CYCLOCEPHALA spp.

The only stages in the life history of Cyclocephala likely to be confused with *Euetheola rugiceps* are the larva and the pupa. The larvæ of Cyclocephala are somewhat smaller than those of *E. rugiceps* and of more yellowish hue. They also differ in the smooth and shiny surface and yellowish amber color of the head shield and in the entire absence of any trace of a median double row of modified bristles on the last ventral segment. The distinctive character of the pupa was not fully studied in this investigation, but the possibility of confusing it with the same stage of Euetheola is largely eliminated by the fact that the two occur at entirely different periods of the year. Thus, at Tappahannock, pupæ of Cyclocephala were obtained from the last of May to the early part of July, whereas those of *E. rugiceps* were never taken before August.

PHYLLOPHAGA spp.

So far as adults of Phyllophaga are concerned there need be no difficulty in distinguishing them from *Euetheola rugiceps*, while the larvæ may be recognized by the reduced size and triangular outline of the supraanal plate, the angular form of the anal slit, the smooth and shiny surface and yellowish color of the head shield, and the presence of a conspicuous, sharply defined, double row of modified bristles on the last ventral segment (Pl. III, *G*).

NATURAL ENEMIES

The data on the predacious enemies of *Euetheola rugiceps* are very incomplete, and little of importance has been added in the course of this investigation. The underground habits of the species render it difficult to obtain direct evidence of predatory enemies, and only a very small proportion of the individuals collected were parasitized.

At Tappahannock the fields infested with *E. rugiceps* were observed to be frequented by flocks of crows, grackles, and bobolinks, which were probably feeding upon the beetles, though direct proof of this was not obtainable. The Bureau of Biological Survey, however, has found specimens of *E. rugiceps* in the stomachs of the crow, meadowlark, and bluebird, and of species of the closely related genus Ligyrus in the stomachs of numerous birds.

Among the possible insect foes of *E. rugiceps* may be mentioned several species of Carabidae (ground-beetles), Asilidae (robber-flies), and ants. Carabid beetles were normally common in underground situations and were of frequent occurrence in the places where *E. rugiceps* has been found, but the writers have no direct evidence that they attack or kill the latter, though it seems likely that the smaller larvæ, at least, may at times be the victims of these predacious beetles. As for the Asilidae, Titus (*13*) mentions the larva

of a robber-fly (*Erax lateralis* Macq.) as an enemy to this and other scarabaeids. At Tappahannock the junior writer observed the larva of a similar or closely related form preying upon larvæ and pupæ of a species of Phyllophaga, but never found it attacking those of *E. rugiceps*. Ants were found to attack and kill any larvæ of the latter or of other scarabaeids that chanced to be exposed on the surface, and it is reasonable to suppose that they would do the same thing underground, an inference which is supported by the observation that rarely, if ever, were scarabaeid larvæ of any kind encountered in the vicinity of ant colonies.

In the junior writer's experience the most frequent enemies are certain mites which attach themselves to the body surface. That these mites derive any nourishment from their host the writers are not prepared to assert. Nathan Banks, then of the Bureau of Entomology, to whom specimens of the mites were sent and who determined them as the hypopus stage of *Rhizoglyphus phylloxerae* Riley, asserts that they are saprophytes, feeding upon decaying vegetable matter. Whatever may be the normal feeding habits of the mites, it is the experience of the writers as well as of other investigators (Davis, *5;* Smyth, *12*) that the presence of these and other mites is highly detrimental to the grubs and also to the pupæ. Upon adults they appear to have little effect. The junior writer has observed adults almost literally encrusted with mites and apparently none the worse for the presence of their uninvited guests. Larvæ and pupæ are more susceptible, however, and it is the opinion of the writers that the high mortality in the larvæ and pupæ in the breeding cages and boxes was due in large measure to the mites. Larvæ have been found in the field with the mites attached to them, so that it is not alone in the breeding boxes that they are attacked.

At Tappahannock in the summer of 1915 these mites were very numerous and troublesome, but in the following year they had all but disappeared. Possibly such fluctuations in the numbers of the mites from year to year may be one of the factors in determining the rather sporadic and irregular manner in which destructive outbreaks of *E. rugiceps* appear to occur.

The larvæ and pupæ were found occasionally to be infested with minute whitish nematode worms. Usually these were observed on the surface, where they tended to congregate in the intersegmental furrows, but sometimes an identical or closely similar type of nematode could be seen, through the transparent body wall, moving about in the body fluid.

There are unquestionably two species of true parasites, one of which, a dexiid fly, W. R. Walton determined as *Megapariopsis opaca* Coq. The maggot of this fly feeds within the body of the larva until it is ready to form the puparium. Those reared by the writers bored their way out of the host shortly before changing to puparia.

The other parasite was a hymenopterous insect, of which none was reared to the adult stage. For this reason the specific identity of the parasite was not determined, but it closely resembles *Tiphia inornata* Say, the best known probably of all the enemies of Phyllophaga as described by Davis (*4, p. 15*) and Smyth (*12*). The young of this parasite is a thick white maggot, which during the time it is feeding lies in a transverse position on the dorsum of its host

immediately behind the head. The few specimens observed by the junior writer in tin salve boxes failed to give up adults. In the field, however, he has found on several occasions the cocoons of what he is inclined to think is the same form. These resemble in general the cocoons of Tiphia and, like the latter, are characterized by having the head shield of the host attached at one end. In a number of cases the head shield of *E. rugiceps* has been found attached to these cocoons, but adults were not reared from them.

All stages of *E. rugiceps*, but more especially the larva and pupa, are subject to infection by a fungus, specimens of which were identified by Dr. A. T. Speare, formerly of the Bureau of Entomology, as *Metarhizium anisopliae.*

CONTROL MEASURES

As has been shown, *Euetheola rugiceps* breeds mainly in low, moist, poorly drained areas that have been allowed to remain as waste or pasture lands for a considerable period of time. In fact under normal conditions these are apparently the only places where the pest breeds in sufficient numbers to constitute a menace to cornfields. Land that is kept in a high state of cultivation, with frequent and systematic rotation of crops, furnishes an unfavorable breeding ground for this beetle. Very few beetles reach maturity in cultivated fields; occasionally quite a number may be found breeding in temporary pastures or hay fields. The numbers of beetles developing in such places, however, are insignificant compared with those breeding in the normal habitat of the species.

ELIMINATION OF WASTE LANDS AND OLD PASTURES

Knowing these facts, by far the most important means of control naturally suggests itself, namely, the elimination of all old waste and pasture lands. All such lands should be thoroughly drained and included in the regular system of rotation practiced for the remainder of the farm. If it seems most desirable to retain these lands for pasture, they should be broken up and reseeded every few years. This would be advisable if only as a matter of good farming, since in localities troubled with this pest pastures will become overgrown with weeds of many kinds in a few years at the expense of the more valuable grasses. The practices suggested will not only destroy the chief breeding grounds of the pest, but will make these lowlands more productive and profitable.

Such pasture lands when broken up should not be planted to corn the first year. As no other cultivated crop is injured by *Euetheola rugiceps*, some other crop can be substituted. The following year corn may be planted, as there is but a single generation of the beetles a year.

PASTURING WITH HOGS

When old waste or pasture lands can not be drained conveniently and included in the rotation, the probability of injury resulting from the presence of these breeding grounds may be eliminated largely by pasturing hogs on such land every year, at least during August and September. The hogs will root out the grubs industriously.

EARLY PLANTING

Since the depredations of the beetles appeared to occur mostly during May and June in 1914 and 1915, experiments were conducted in 1916 at Tappahannock to learn something of the possibilities of control by early planting. The earliest plantings were on April 7, and plantings continued at two-week intervals until June 19. Though the test was too short to be conclusive, the results indicated that May plantings suffered the greatest injury from *Euetheola rugiceps*.

CHANGE OF ROTATION

As previously stated, corn should not be planted after sod where there is the prospect of injury from the beetle. Besides the rough-headed corn stalk-beetle, sodworms and cutworms are always a source of danger to corn planted on old sod land. Therefore any system of rotation which obviates the necessity of following sod with corn helps to avoid several serious insect pests.

FERTILIZERS

The application of barnyard manure or commercial fertilizers is beneficial, because growth is hastened and the corn plants are thus enabled more quickly to reach a state where they are less likely to be injured seriously.

HAND PICKING

Hand picking is at best only a temporary expedient and in most cases very expensive. When a field of growing corn has become infested, however, there is no other hope of relief. Cheap labor sometimes may be employed to collect and destroy the beetles found in young corn. This work should be done principally when the corn is being either plowed or thinned.

LATE SUMMER PLOWING

The rough-headed corn stalk-beetle enters the pupa stage during the latter part of August and it is in this stage that the insect is most easily destroyed, the least disturbance being sufficient to kill the pupæ. For this reason, wherever possible, sod lands should be plowed the last week in August or the first week in September for Virginia but earlier than this for more southern localities.

SUMMARY OF CONTROL MEASURES

Eliminate all old pastures or waste land, especially low, moist areas, and drain such lands thoroughly.

Pasture hogs in waste or pasture lands that can not be conveniently drained and cropped.

Plant corn early, say about April 20 for tidewater Virginia, and earlier for more southerly localities.

Give liberal applications of barnyard manure or commercial fertilizers whenever practical.

Employ cheap labor to collect and destroy the beetles when a field first shows injury.

Do not allow corn to follow sod if possible to avoid it.

Plow sod land in late summer and early fall in order to destroy the pupæ of the rough-headed corn stalk-beetle.

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